# One Year Status Report
# Eradication and Surveillance of *Caulerpa taxifolia* within Agua Hedionda Lagoon, Carlsbad, California

**September 2001**

## Executive Summary

On June 12, 2000 the first known infestation in the Western Hemisphere of the invasive strain of the tropical alga, *Caulerpa taxifolia*, was discovered in Agua Hedionda Lagoon, in Carlsbad, California. This document outlines the activities that have been undertaken during the first year of what is anticipated to be a five year program to eradicate this species from the lagoon system. It also outlines the anticipated future actions needed to effectively complete the eradication effort. Actions have been taken under the oversight of the Southern California Caulerpa Action Team (SCCAT), a broad-based task force assembled from federal and state resource and regulatory agencies, exotic species experts and marine resource scientists.

During the first year, much has been accomplished in the *Caulerpa* eradication effort, yet much still remains to be done. The eradication program being employed within Agua Hedionda Lagoon consists of survey and treatment elements in which saturation surveys are used to seek out *Caulerpa,* which is subsequently treated by the application of chlorine under vinyl containment tarps. Year 2000 surveys revealed the presence of slightly less than 75% of the *Caulerpa* believed to have been present within the lagoon during 2000. The summer and fall of 2000 was a period of aggressive treatment and high expenditures on treating large patches of *Caulerpa*. The largest single patch was estimated to have a biomass in excess of 20 tons of the alga. All of the 11,310 square feet of material known to exist in 2000 was treated, resulting in a 97.72% reduction of *Caulerpa* within the 2000 eradication area prior to 2001. Because of the significant reduction in the extent of the alga, in 2001 the focus shifted away from localized treatment and more towards heavy surveillance and treatment where previously undetected infestations were found. By the summer of 2001, the survey intensity was five times greater than in the summer of 2000. With this increased survey intensity, five additional infestation areas were identified and treated, totaling approximately 27% of the total algal cover as found and treated in 2000. In the first year of the program, approximately $1.1 million was spent on eradication at the lagoon.

While the extent of *Caulerpa* continues to be reduced as the second year of the eradication effort continues, the intensity of surveys used to locate remaining patches is rising, increasing effort and cost. As a result, surveillance is replacing treatment as the most costly element of the eradication program. During the ensuing years, it is anticipated that a comparable annual budget to that invested in the first year's program will be required to continue to locate and treat remaining patches of *Caulerpa*. Early results from the eradication efforts are promising, but it is imperative that the program be completed in order to ensure effectiveness.

## Background

The highly invasive Mediterranean strain of the tropical alga, *Caulerpa taxifolia*, has become established in Agua Hedionda Lagoon, Carlsbad, California. This site, identified in June 2000, represents the first known occurrence of this strain within the Western Hemisphere and is a major threat to coastal ecosystems and recreational and commercial uses dependent upon coastal resources. While the species has now been identified at a second site in California, Agua Hedionda represents the larger of the known infestations and has likely been in the lagoon for at least four years prior to its discovery. It is not known whether other infestations also exist and the continued wide availability of this species on the commercial aquarium market is of high concern.

*Caulerpa taxifolia* has been banned from international import or interstate commerce since 1999 through the Federal Noxious Weed Act. Legislation banning the transport, sale, and possession of several potentially invasive species of *Caulerpa* was recently approved by the California State Legislature and was signed into law by the Governor on September 24, 2001.

Since the discovery of *Caulerpa* in Agua Hedionda in June 2000, eradication, surveillance, public outreach efforts, eradication research, and legislative efforts have been initiated and are on-going. The primary, but not the sole, focus of SCCAT has been on eradication of the known infestations. However, given that there may be other infestations that have yet to be identified, that the alga is still commercially available and there is a high risk of new introductions, and that no current effective eradication mechanisms in high-energy areas have been identified in either Europe or the U.S., resources have been allocated to a diverse range of needs as best seen fit within the mandates of the funding and supporting agencies.

*Caulerpa taxifolia* eradication efforts within Agua Hedionda Lagoon are currently underway. These efforts include both survey and treatment components. Using the present resources available through state and federal agency funding, and funds previously committed by Cabrillo Power I LLC (Cabrillo), work has been underway for one year in contemplation of a five-year program for eradication of *Caulerpa* from Agua Hedionda Lagoon.

This document provides a synopsis and retrospective on the first year's efforts and identifies what can be expected over the future years with respect to the eradication program. It outlines how the program has evolved over the past year and outlines a course for the future with a goal of full eradication of *Caulerpa* from Agua Hedionda Lagoon.

## 2000-2001 Eradication Program

### *Early Actions Taken*

Development of a program to eradicate the *Caulerpa* infestations began in June 2000, within a week of identifying the species. The first actions taken were: 1) assembly of a multiple agency task force (the Southern California Caulerpa Action Team (SCCAT)); 2) continued assessment of the magnitude of the infestation in the lagoon; and 3) identification of effective treatment options through review of European efforts to combat this species and laboratory testing of a variety of treatment options. This work was outlined in the Rapid Response and Eradication Program for the Invasive Green Alga, *Caulerpa taxifolia*, at Agua Hedionda Lagoon, Carlsbad, California.

The eradication program being employed within Agua Hedionda Lagoon is comprised of both survey and treatment components. Extensive diver surveys are employed to locate *Caulerpa* and treatment involves applying chlorine under vinyl tarps that cover the substratum.

Based on the initial actions outlined for the eradication, an estimated 5-year program to eliminate *Caulerpa* from the lagoon was established. The eradication treatment efforts were initiated in July 2000. Throughout the second half of 2000, the extent of the infestation was believed to only occupy large portions of Snug Harbor within the easternmost of three lagoon basins (Inner Lagoon). The approximately 5.7 acre area within Snug Harbor was bounded by a boom and a grid was established over the infestation area to facilitate systematic surveys and treatment. Of the 1,024 grid cells, 145 were found to contain *Caulerpa*. A debris field in which small patches of the alga were present occupied approximately 1.45 acres. In total, 11,310 square feet of *Caulerpa* was identified within the grid, including 13 major patches (over 100 square feet each).

Initial efforts during the late summer and fall of 2000 were focused principally on treatment of the *Caulerpa* known to be present within Snug Harbor. While treatment was taking place within Snug Harbor, other portions of the Lagoon were being surveyed using diver transects spaced at 5 meters on center. Within the westernmost basin (Outer Lagoon), comprehensive surveys were conducted on two separate occasions prior to the completion of maintenance dredging by Cabrillo Power's Encina Generating Station. By the end of September 2000 all of the *Caulerpa* known to exist at the time had been treated.

Through monitoring surveys conducted in the Lagoon, areas of *Caulerpa* not discovered during summer and fall 2000 surveys were found. Fall 2000/Winter 2001 surveys were hampered in November 2000 by massive natural diebacks of eelgrass that matted down over the bottom making it nearly impossible to locate any of the shorter *Caulerpa* that may have been present. By the next quarterly survey, conducted in February 2001, the eelgrass had fully shed dead blades, exposing the bottom throughout most of the lagoon. At this time, it became clear that previously undetected *Caulerpa* had over-wintered and

that more intensive surveys were necessary to detect all of the infestation areas, especially considering the fact that smaller patches were now being sought. It also became clear that the extent of the infestation area identified in 2000 was an underestimate and that patches of *Caulerpa* actual occurred throughout the of entire Snug Harbor and even occurred further east in the Inner Lagoon. As a result of these findings, surveys were intensified to 3-meter center transects and were ultimately shifted to 1-meter center transects by early summer 2001.

***Second High Growth Season***

While the initial efforts in the eradication program were principally reactive and focused on the treatment of extensive occurrences of *Caulerpa* found in the Inner Lagoon, the greater focus on intensive survey during the second high growth summer season revealed additional *Caulerpa* that had been overlooked in 2000. In total, six centers of infestation were noted within the Lagoon, with all locations occurring within the Inner Lagoon. High turbidity within the easternmost portion of the Inner Lagoon may screen additional sites that remain undetected at the present time. Surveys have continued to focus on this area during summer and fall of 2001.

During spring and summer of 2001 a total of 315 square feet of *Caulerpa* was detected within 69 of the original grid cells identified in 2000. This algal material was spread over a 40,885 square foot debris field. Preliminary estimates outside of the grid for summer 2001 have identified a total of 3,040 square feet of *Caulerpa*, including five major patches in five infestation areas as of September 25, 2001. The debris fields for these infestations occupied 101,828 square feet. Final estimates for the lagoon are anticipated to be available by October 15, 2001.

Through the spring and summer of 2001, eradication treatment efforts continued on newly identified sites and within areas surrounding previous treatment areas. Refinements of the treatment approach were made to expand treatment beyond limits of detected *Caulerpa* to include a minimum buffer of 3 meters when treating large patches. This was done based on the findings of the prior year that indicated very small and easily overlooked fragments were common in close proximity to detectable patches. Patches identified during the spring and summer 2001 were treated using the techniques outlined for the overall program.

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Because only a portion of the infestation was detected during 2000, it is not possible to fully evaluate the change in *Caulerpa* status from summer 2000 to summer 2001 throughout the entire lagoon. However, it is possible to examine changes within the infestation area that was known to exist in 2000 and to establish a 2001 baseline against which future changes throughout the entire lagoon may be evaluated.

*Caulerpa* infestations can be characterized both by areal coverage (quantitative extent) and dispersion (spatial distribution patterns). Lacking sexual reproduction, this strain of *Caulerpa taxifolia* only spreads by fragmentation or growth. Over the course of the year, it has been determined that the *Caulerpa* infestations typically exhibit a clumped distribution pattern where a central core patch is surrounded by fragments that initiate new patches that can also fragment and spread. As a result, infestation areas are defined by a number of closely associated patches. These are commonly made up of major patches, if they have been present for over a year, and debris fields of associated small patches and fragments. *Caulerpa* can move greater distances through dispersal of fragments by means that are not quite fully understood. In the Mediterranean Sea, it has been noted that *Caulerpa* is moved long distances by vessel anchors. At Agua Hedionda Lagoon, this mechanism, along with fishing, was identified as the primary controllable risk of spreading *Caulerpa*. As a result the City of Carlsbad was requested by the SCCAT to assist in the control of spreading the alga by banning fishing and anchoring around the infested area. The City took this action and provided their Police Department with the authority to enforce and expand the ban where necessary. This ban is now being enforced by the Carlsbad Police Department and the California Department of Fish & Game. Within the most significant area of infestation, all boating and access has been temporarily eliminated to aid in the eradication efforts.

Within the infestation area that was known to exist in 2000, the results observed from the eradication efforts have been very positive. All major patches have been eliminated and the total areal coverage of *Caulerpa* is down by 97.3%. Lesser, but still significant, reductions have occurred with respect to the area of the debris field around patches and the number of cells in the grid that were found to support *Caulerpa* (see Table 1). An area of infestation cannot be considered eliminated until there has been no *Caulerpa* detected for a period of two or more years with intensive searches.

**TABLE 1. STATUS WITHIN GRID AREA**

| Parameter | 2000 | 2001 | % Reduction |
|---|---|---|---|
| Areal Extent (sq.ft.) | 11,310 | 315 | 97.3% |
| Number Major Patches | 13 | 0 | 100.0% |
| Debris Field Area (sq.ft.) | 63,032 | 49,261 | 21.8% |
| Number of Dirty Cells (1024 total) | 145 | 85 | 41.4% |
| Number of Infestation Areas | 1 | 1 | 0.00% |

Outside of the grid, *Caulerpa* was discovered during the 2001 surveys and thus no data on the size or extent of the infestation that was present in these areas in 2000 are available. However, it is believed that these *Caulerpa* patches were present in 2000 and were missed in the earlier, lower intensity surveys of the lagoon. All of patches were treated by the end of the summer 2001. Data for 2001 therefore reflect a baseline against which future eradication progress can be judged. *Caulerpa* found outside of the initially identified infestation area comprises approximately 27% of the total found in 2000 although the area over which this material was distributed included approximately 161% of the total area known to exist in 2000 (see Table 2).

**TABLE 2. STATUS LAGOON-WIDE (EXCLUDING GRID)***

| Parameter | 2000 | 2001 | % Reduction |
|---|---|---|---|
| Areal Extent (sq.ft.) | unknown | 3,040 | NA |
| Number Major Patches | probably 5 | 5 | NA |
| Debris Field Area (sq.ft.) | unknown | 101,831 | NA |
| Number of Infestation Areas | 5 | 5 | 0.00% |

* Preliminary data as of September 23, 2001

The grid-survey results suggest that the eradication approach is effective in treating Caulerpa with the goal of full eradication. However, this report only addresses year-one in a long-term program and diligence in implementation will be essential in order to avoid backsliding. The following section outlines future program plans and needs.

## Future Actions in the Eradication Program

### *Expectations of a 5-year Program*

The first year of eradication work provides insight into what can be expected over the course of future eradication efforts. The first year data also indicate that the initial action plan contemplation of a 5-year eradication program was not unfounded. The reappearance of *Caulerpa* within the grid was expected. The propensity for *Caulerpa* to vegetatively disperse through fragmentation means that regardless of initial successes, multiple years of surveillance and eradication are necessary to find and address very small fragments as they grow to a detectable size. While the precise length of time it may take to rid the lagoon of *Caulerpa* may vary from the 5-year estimate, the general schedule fits well with observed reductions in 2000-2001.

As the eradication program continues, it is anticipated that surveillance efforts will dominate over treatment efforts in terms of both costs and time. With the biomass and areal coverage of *Caulerpa* significantly reduced, efforts are now focused on seeking smaller patches over larger areas. Intensive surveys seeking the earliest possible detection of newly colonizing patches will be the focus during the subsequent year (2001-2002) and possibly a third year. The large reduction in patch cover since the inception of the eradication effort means that patches can now be treated within 48 hours of discovery. Such a rapid response ensures minimal fragmentation and will help to ensure that the program timeline is kept to a minimum. Given the progress that has been made, it is hoped that by the end of the third year no new occurrences are identified and surveys would be performed for the purpose of designating areas as non-infested. Two additional years (years 4 and 5) would be used to conduct surveys to ensure that no remaining *Caulerpa* exists. Only after at least two years of surveillance without detection would the lagoon be declared free of *Caulerpa*.

### *Enhancing the Caulerpa Detection and Eradication Efforts*

While it is essential that the present program be maintained to effectively eradicate *Caulerpa* within the lagoon, there are also opportunities to enhance the program by increasing the intensity of surveys. This enhancement of the program is currently limited by available funding and conflicts of safety and efficiency between the eradication efforts and recreational uses within the lagoon.

The present eradication program includes two surveillance levels. The first is a high intensity surveillance that is being used in regions of the lagoon where *Caulerpa* has not previously been identified. The second is an even higher intensity eradication area survey. Although survey intensity has increased five-fold (greater diver density) since initiating work on the eradication program, still higher intensity would be helpful. The present program calls for quarterly surveys of the entire lagoon. This program is proposed to continue in the future. If additional resources were available, it would be preferable to conduct monthly surveys of the lagoon during the period of highest growth (May through September) and to intensify and expand survey areas around eradication sites. Such actions would allow more rapid identification and treatment of patches and would ensure that the rate of elimination of alga from the lagoon was increased.